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Tolppanen, Sakari

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Sakari Tolppanen & Maija Aksela

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ABSTRACT
This study uses qualitative content analysis to examine 355 open-ended questions, presented by 16-19 –year-old international students, to find out what students want to learn about climate change. The study finds that students have a high level of consideration towards scientific, societal and ethical aspects of climate change and that students' questions are multidisciplinary and complex in nature. Most importantly, the findings show that students ask questions on the same themes that researchers say should be addressed in multidisciplinary climate change education. Based on the findings, this article suggests that climate change education could be developed by adopting guided inquiry.

KEYWORDS: Climate Change Education, Students Questions, Content Knowledge, Systems Thinking, Guided Inquiry,

INTRODUCTION

Sustainable development is commonly defined as development that meets the needs of the present without compromising the ability of future generations to meet their needs (World Commission on Environment and Development, 1987). However, our current behavioral patterns are causing the climate to change, and endangering future development (IPCC, 2014). Because of these global changes, governments are committed to mitigate climate change (Center for Climate Change and Energy Solutions, 2015) and climate change education is seen as important in many countries (Schreiner, Henriksen, Kirkeby, & Pål, 2005). However, climate change and climate change mitigation and adaptation are complex phenomena environmentally, societally and economically; bringing many challenges to climate change education. Therefore, in order to develop climate change education, more research on the topic is needed.

This paper first introduces some of the challenges of climate change education. The paper then examines students' questions on climate change to find out what students find relevant about climate change. Based on the findings, the authors then discuss what type of content knowledge is needed to answer students' questions holistically. Finally, the paper discusses the challenges of addressing students' questions, and suggests ways to overcome these challenges.

Challenges of Climate Change Education

One of the challenges of climate change education is that knowledge about climate change is highly affected by the media (Schreiner *et al*., 2005; Svihla & Linn, 2012). As a consequence, even before starting class, there may be significant differences in the students level of understanding regarding climate change. Another challenge for climate change education is the complexity of the science behind climate change (Svihla & Linn, 2012). As an example, climate change is an invisible phenomenon (Schreiner *et al*., 2005): we cannot observe changes in short time increments, but need to look at statistics over a longer time period and on a global scale. Furthermore, the societal aspects are also complicated, as climate change will affect people living in different regions in different ways, typically affecting poorer nations more than the rich (IPCC, 2014). In addition, both climate change and climate change mitigation affect the economy. In order for individuals, nations and international organizations to make mitigation decisions, the cost benefits must be weighed using complex predictions where environmental, societal and economic aspects are considered. However, making such calculations, especially on a national or global scale, seems to be almost an impossible task. In essence, understanding climate change, its causes and possible ways of mitigation, requires systems thinking: a way of thinking that considers the system as a whole, rather than a sum of the parts (Tilbury & Cooke, 2005).

Further challenges are presented by teachers' lack of professional training and experience in teaching on climate change. Earlier research has shown that teachers hold misconceptions about the scientific aspects related to climate change (Ocal, Kisoglu, Alas, & Gurbuz, 2011; Papadimitriou, 2004). One of these common misconceptions is that ozone depletion contributes to climate change (Papadimitriou, 2004). Furthermore, teachers have emotions regarding climate change education, varying from anger to hopelessness (Lombardi & Sinatra, 2013). These emotions may affect the way they deal with and talk about the topic in class.

Numerous studies show that students' knowledge on the science of climate change is limited and that students hold many misconceptions (e.g. Andersson & Wallin, 2000; Pruneau, Moncton, Liboiron, & Vrain, 2001; Shepardson, Niyogi, Choi, & Charusombat, 2009). Some of the most common misconceptions are that students believe that ozone depletion (Pruneau *et al.*, 2001; Shepardson *et al*., 2009), and air pollution in general (Andersson & Wallin, 2000; Shepardson *et al*., 2009), contribute to climate change. Students' emotions may also affect their motivation to learn about climate change mitigation, as students easily feel that their individual contribution to climate change or climate change mitigation is insignificant (Schreiner *et al*., 2005).

Further challenges to climate change education, and environmental education (EE) in general, are caused by the way our education system is built. Stevenson (1987) has argued that, historically speaking, our schools were not intended to develop problem solvers, critical thinkers or active participants of society. Rather, they were structured to give basic information and enable practical routine skills. These structural aspects are still seen today (Stevenson, 2007) in the way environmental topics are divided into different subject groups. For instance, traditionally, reactions of greenhouse gases are taught in chemistry, thermodynamics is taught in physics and the carbon cycle is taught in biology (and chemistry), though all of them play a key role in understanding climate change as a system. What is worse, this list does not even begin to tackle the societal issues related to climate change or the technical solutions available to reduce climate change. Fortunately, this challenge has been acknowledged, as is seen from the way some of the newer national curricula aim to support cross-disciplinary education (e.g. Finnish National Board of Education, 2014). However, it may take time before these changes are implemented effectively, as teachers may not yet have the appropriate skills to conduct multidisciplinary education (Ratinen, 2016).

Though many challenges are presented here, this list is by no means a complete list of the challenges faced by climate change education. However, it does demonstrate the diversity of the challenges and points out that climate change education is challenging for teachers, as well as on a scientific and societal level.

Approaches to Climate Change Education

Sterling (2010) has highlighted, that there are some tensions in what educators consider the primary focus of environmental education. Some see environmental education as the means to individual and societal change, whereas others see it as a means to support autonomous learning, whether it leads to action or not. To overcome this tension, Sterling suggests that the focus should be in educating “resilient learners”: people who are able to face uncertainty and surprise. Such an approach acknowledges that climate change is a wicked problem (see Levin, Cashore, Bernstein & Auld, 2012), where simple solutions to the problem do not exist. In order to achieve this, it is necessary for students to understand the interrelations involved in climate change and its mitigation. Many scholars, including Sterling (2004) and Seiffert & Loch (2005) have argued that systems thinking is both necessary and useful in examining and understanding these interrelations. Systems thinking is a technique that builds bridges and connections between components that are part of a bigger system by examining a system as a complex entity of many interconnected systems that need to be taken into consideration simultaneously (Salonen, 2010). Therefore, systems thinking focuses on building a whole picture of a phenomena, rather than breaking it down (Flood, 2001 p. 133). This involves increasing the level of abstraction or overview of a topic, rather than reducing a topic into smaller parts (Sterling, 2004). In other words, much content knowledge is needed in order to examine an issue systemically. Therefore, this paper examines what type of content knowledge should be addressed in climate change education to support systems thinking. In this pursuit, it is important to examine what knowledge is relevant for students.

Shepardson *et al*. (2012) have presented a scientific approach to climate change education, arguing that in order for students to understand and have adequate information about climate change, the students need to understand climate as a system. In their model (named: *Climate System Framework*), they present six key domains which they argue are crucial in understanding climate change as a system. These domains are (see Shepardson *et al*., 2012 for more details):

1. Natural causes and changes to the climate system
2. Atmosphere and pollution
3. Snow and ice levels
4. Oceans (levels, temperature and life)
5. Land and vegetation
6. Human impact

Educational models, such as the one above, provide guidelines on what kind of scientific knowledge students should have about climate change. However, they do not address individual and societal issues such as: what can students do to combat climate change, or how politics, economics and ethics affect the way we perceive and deal with climate change? Therefore, their relevance on an individual and societal level is limited. The other challenge with such models is that the emphasis is in providing students with a certain predetermined set of knowledge, which may lead to an oversimplified understanding on the issue.

To expand beyond a scientific approach to climate change education, Andrey & Mortsch (2000) have presented that climate change education should address:

1. Climate change as a complex issue
2. Numerous uncertainties in climate science
3. Impacts of climate change which are borne disproportionately by people in different parts of the world
4. Causes of climate change that are embedded in our preferred lifestyle

To extend this list, Schreiner *et al*., (2005) argue that climate change education should also discuss how:

5. Climate change is a media issue
6. Climate change is an invisible phenomenon
7. Climate change occurs on a long time scale
8. Individuals are not held personally accountable for actions that cause climate change
9. There are many competing environmental and political interests
10. Individuals' contribution is significant to climate change

As the lists suggests, researchers suggest a large number of issues to be covered in climate change education. This study examines how these issues relate to what the students find relevant and discusses how these issues could be addressed in a way that supports systems thinking, and resilient learning. Firstly, let's briefly examine why students' questions should be analyzed.

Using Students' Questions to Support Education

A moderate number of studies have been conducted to determine how students' questions could be used to improve education. For instance, researchers have discussed that students' questions give insight into how they think (Mitchell, 2010), what type of mental models they have (Aguiar, Mortimer & Scott, 2010; Chin & Osborne, 2010) and what type of interests they have (Demirdogen & Cakmakci, 2014). Therefore, analyzing and understanding students' questions can help guide the learning process.

In previous research, students' questions have usually been studied in classroom settings, in which students ask questions directly to the teacher or to each other. However, this may give a limited view on students mental models and interests, as these questions may be asked spontaneously and are affected by the classroom settings (Graesser & Personin, 1994). Therefore, this study focuses on examining questions that students ask while being in an environment of their choice and when they have all the time they want to formulate their questions. By analyzing these questions, this study gives insight into what students want to address in climate change education and how these questions could be used to improve climate change education.

AIM

The aim of this study is to answer the question: What type of questions do 16-19-year-old students ask about climate change? By answering this research question, this study aims to give educators an understanding of the type of issues that students find relevant regarding climate change and how these issues could be addressed holistically to support systems thinking.

METHOD

Data Collection

The data for this study was collected from camp applications for the international Millennium Youth Camp (Finland's Science Education Centre, 2012) held in 2011. The camp was aimed for scientifically and mathematically gifted students aged 16–19 years old who had shown their interest in the subjects through competitions, school success or their own research projects. The program was advertised to embassies around the world, who then contacted scientifically and mathematically oriented schools. The application was also advertised in public schools around the world, where a representative could be contacted to manage the matter. The online application was open to everyone, but students from the contacted schools mainly applied.

When applying to the camp, the applicants were asked to choose one of the five theme groups of the camp: *Climate change*, *Renewable energy and resources*, *Water*, *ICT* or *Applied mathematics*. In the application, students were also asked open-ended questions to find out what issues related to their chosen theme they would want to know more about. Demographic questions regarding age, gender and country of origin were also asked. The application also included other general information questions that are not relevant to this study.

Participants

A total of 1453 camp applications (51% females and 49% males) were received. Of these, 300 applications selected the *Climate change* group, but due to the small amount of applications from Oceania, South America and North America, only applications from Asia and Europe were analyzed in this study (n=250).

Of these applicants, 200 presented one or more question related to climate change that they would desire answers to. The rest (n=50) of the applicants either did not present any questions, or they presented questions that did not concern climate change. These irrelevant questions included concerns about the structure of the camp, the staff and camp expenses.

From the 200 applicants who presented questions relevant to climate change, 132 (66 %) were female and 68 (34 %) were male. The applicants were 16 to 19 years-old (with a mean age of 17.6). Sixty-six of the applicants were from Asia and 134 from Europe, representing a total of 46 countries. The applicants presented a total of 355 questions. Due to the application process, it is fair to assume that all of these 200 applicants were interested in climate change issues.

Data Analysis

Content analysis was used to analyse the data (see Cohen, Manion & Morrison, 2007). First, the students' questions were categorized using inductive and deductive content analysis. Following analysis of the data, the researchers discussed whether some categories could be combined or renamed and made changes accordingly. The data was then analysed again, using these new categories. The quality of the derived categories was tested by giving 10% of the data to an outside researcher to categorize. The similarity of the two categorizations was analyzed with Cohen's kappa analysis:

$$\kappa = \frac{Pr(a) - Pr(e)}{1 - Pr(e)}$$

where *Pr(a)* is the relative observed agreement between the researchers and *Pr(e)* is the hypothetical probability that agreement happens by chance (Cohen, 1960). The agreement between the two researchers was found to be good (K=0.82).

Furthermore, differences between gender, continent of origin and age were analysed with the Mann-Whitney U test.

RESULTS

In this study, 200 international students presented 355 open ended questions on what they would want to learn about climate change. The presented questions were placed into five categories derived from the content. These categories were: *Climate System Framework*, *Effects on Humans*, *Solutions for Climate Change*, *Raising Awareness* and *Human Action*. These categories are further discussed below (Table 1).

Table 1: The types of climate change related questions presented by the applicants by gender

		In Sample n (%)	Solutions for climate change N (%)	Climate System Framework N (%)	Human Action N (%)	Effects on Humans N (%)	Raising Awareness N (%)	Questions presented, in total N (%)
Gender	Female	132 (66%)	89	69	32	26	15	231 (65%)
	Male	68 (34%)	43	48	14	12	7	124 (35%)
Total			132 (37%)	117 (33%)	46 (13%)	38 (11%)	22 (6%)	355 (100%)

Solutions for Climate Change

The students were most concerned about finding solutions to the problems related to climate change (37%, n=132). The students asked about a wide range of available solutions, which were divided into three sub-categories: *Practical Solutions*, *Science and Technology Related Solutions* and *Solutions Related to Renewable Energy and Resources.*

Practical Solutions

Over two thirds (n=91) of the solution-oriented questions presented by the students were practical in nature. In essence, the students wanted to know if there is anything *they* can do to help mitigate climate change. An example of a question in this sub-category was presented by an 18-year-old female student from Asia:

> *In our Biology lessons we learnt a lot about the world's ecological problems like acid rain, greenhouse effect, ozone depletion and others. We know many reasons why such problems appear, but I want to know solutions too.*

Another example was presented by a 17-year-old female student from Europe who expressed a need to find solutions to climate change before her local habitat is threatened:

> *I would like to learn if there may be any way to combat future sea level rises. This is of interest to me because I live in a coastal area.*

Science and Technology Related Solutions

Some (n=25) of the students wanted to know how new inventions or implementations of science and technology could help solve the problem of climate change. For instance, an 18-year-old female from Europe expressed her interest in this issue with this sophisticated statement:

> *I think exploring one or more potentially very effective geoengineering techniques would be really interesting. Carbon sequestration was covered last year [at the camp], but there are of course plenty of other interesting methods as well. It unfortunately seems very possible that it needs to be used at some point in the future if climate change and/or its effects cannot be significantly reduced.*

Solutions Related to Renewable Energy and Resources

A few (n=16) of the solution-oriented questions related to renewable energy and resources. The students wanted to know how these could be used more efficiently to decrease greenhouse gas emissions. Although these questions also relate to science and technology, a distinction was made to highlight the connection that students made between energy and climate change. An example of a question placed into this category was presented by a 19-year-old female student from Europe:

> *How to make renewable sources of energy cheaper and more available to the public? Also, how could they be made more compact and adapted to our everyday life?*

Climate System Framework

Students raised many questions (33%, n=117) concerning the Climate System Framework. This category included questions related to natural causes and changes to the climate system, atmosphere and pollution, snow and ice levels, oceans (levels, temperature and life), land and vegetation, and human impact (see Shepardson et al., 2012). In this instance, human impact refers to how humans affect climate change, but not to how climate change affects humans. In other words, the category of Climate System Framework included all questions that demonstrated that the students wanted further information on the *science* of climate change or have misconceptions about it.

This is a broad category that mainly included general questions about how the climate is changing and how it affects the ecosystem. The most typical questions in this category were similar to the following two examples. A 17-year-old male from Europe stated:

> *I would like to learn more about the greenhouse effect and how it is affecting biodiversity/various organisms (not only humans; animals and plants as well) around the world, i.e., how it is affecting various ecosystems such as the Great Barrier Reef?*

Also, an 18-year-old female from Europe asked:

> *Global Warming has been attributed to man's pollution of the environment. However, can the present heating of the atmosphere be caused by the natural cycles of cooling and heating within our atmosphere? I am aware that the earth goes through cycles, but can Global Warming simply be explained as one of these processes? Is there substantial evidence to support that it is a man-made phenomenon?*

As in the question above, some students doubted whether climate change is a human-induced phenomenon or even if it is really happening. Students also showed an interest towards how climate change research is conducted. An 18-year-old female applicant from Europe wrote:

> *I would be interested in a quick overview of the major research projects and international collaboration in climate science that is going on in the world.*

Human Action

Some students (13%, n=46) also showed that they wanted to know about what kind of action humans are taking to combat climate change around the world. The students asked about political decision-making, global agreements and examples from those countries that are doing a lot of climate change mitigation. In addition, the students showed concern about why people are not acting more rigorously to combat climate change. They also wanted to know more about consumerism and the psychology of human behavior, related to climate change. For instance, a 16-year-old female student from Europe wanted to know more about non-governmental organizations (NGO) and what they are doing to combat climate change:

> *It also seems to me that learning about international organizations is an important part of studying climatic changes. I'll be very glad to learn more about what all these organizations do. I'd like to understand how they do it, how many people are involved, where do they get money. I just want to understand the whole process and to be able to think about the real help I can provide being just a teenager. I'll be happy to learn if there are any international ecological organizations uniting teens.*

Another 19-year-old female student from Europe wanted to know more about what governments are doing:

> *I want to know how the governments of each country give their contributions and help citizens live safely in an auspicious environment. I want to know more about the laws and legislation regarding environmental protection and how they influence violators.*

Effects on Humans

The questions also showed that students wanted further information on how climate change will affect humans (11%, n=38,). These effects include how rising water levels, droughts and more frequent storms will impact humans. Students also showed concern for the spreading of diseases, as well as the effects of increased temperatures on human health, especially the health of elders. This category also includes questions where the students mention indirect effects on humans, such as the effects on the economy.

The following example presented by a 17-year-old female from Europe represents a typical concern in this category:

> *(I want to know about) its influence on people's lives and performance due to rising levels of seas and oceans.*

Another example from a 17-year-old male from Europe:

> *What are the consequences for the economy of limiting CO_2 emissions?*

Raise Awareness

While not very common, some students (6%, n=22) pointed out that their biggest concern was to raise awareness of climate change. Some of these students seemed to have a clear picture of how to achieve this but needed support, whereas others saw raising awareness as an important goal but were still seeking ways to do so. A personal approach to raising awareness was presented by a 19-year-old female from Europe. She wondered:

> *How can I convince my friends and family to save energy, use less water, segregate rubbish etc.?*

Whereas, a 16-year-old female student from Europe took a broader perspective:

> *I want to discuss how we can conceptualize the combination of lectures, workshops, panel debates, educational role-play games and other different program elements, as well as youth participation in promoting street action for climate change. How youth can participate in the delineation of national reform policies for youth and integrated social support for vulnerable adolescents and adolescents from vocation schools.*

Statistical analysis

Correlation between the groups was examined, and the *Climate System Framework* was found to have a weak negative correlation with the categories *Raise Awareness* ($\rho=-0.190$, $p<0.01$) and *Human Action* ($\rho=-0.239$, $p<0.01$). Though the differences between gender, continent of origin and age were analysed with the Mann-Whitney U test, differences were only found in the category *Climate System Framework*, in which the male students were significantly more interested (n=48, 41%) in these issues than female students (52%, n=69), $Z(1, n=117) = -2.484$, $p<.05$.

DISCUSSION

The climate change related questions analyzed in this study shows that, although the students participating in the study were all interested in climate change, there was great variation in their areas of interest, regarding the topic. In essence, the multidisciplinary and complex nature of climate change is reflected in the students' questions. Furthermore, in alignment with previous research (e.g. Tirri, Tolppanen, Aksela & Kuusisto, 2012), the findings indicate that even in a scientific context, students do not ask questions merely related to science: on the contrary, students ask a wide range of questions, ranging from politics to psychology and from economics to individuals' behavior. Educational researchers (e.g. Schreiner *et al*., 2005) have discussed the importance of bringing the multidisciplinary nature of climate change into education and the findings of this study indicate that, at best, a multidisciplinary approach can be achieved by addressing students' questions on climate change. How these questions could be addressed to support systems thinking and a holistic view of climate change will be discussed below in further detail.

Addressing Students' Questions Holistically

The students' questions show that they want answers to many of the same climate change issues that educational researchers have said should be implemented into climate change education (see Shepardson *et al*. 2012; Svihla & Linn, 2012; Schreiner *et al*., 2005). However, as the questions presented by the students are multifaceted, answering the questions requires understanding of climate change from many different perspectives. These aspects include at least scientific, technological, societal, individual and ethical aspects and how these aspects are linked to each other. Nonetheless, students' questions should be addressed holistically, rather than through simple truths, in order for them to gain an understanding of the multifaceted nature of climate change and enhance their skills in systems thinking. The following section discusses why and how this could be done from several different viewpoints.

Addressing Scientific Aspects:

The results of this study show that students want to understand the physical phenomena behind climate change, the research methods used and how trustworthy the results are. This interest towards the science of climate change was especially apparent in male students. Shepardson *et al*. (2012) have presented the *Climate System Framework* as a guideline of the scientific aspects that students *should know* about climate change, in order to understand the environment as a system. Based on the findings of this study, understanding this framework is crucial in answering students' questions.

However, in addition to the *Climate System Framework*, answering students' questions requires understanding of the nature of science (NOS), as only this will make it possible to answer questions related to climate change research and the trustworthiness of scientific findings. Hodson (2008, 2011) has highlighted the importance of teaching about the trustworthiness of scientific research, the nature of science and socio-scientific issues in general. However, the importance of such discussions in a climate change context have not yet received much attention. As the data collected in this study shows that questions related to NOS occur naturally in the context of climate change, climate change education would seem to be a suitable context for NOS discussion. However, earlier research in another context has shown that increased understanding of NOS does not seem to correlate with making more informed decisions about scientifically based personal and societal issues (Bell & Lederman, 2003). Therefore, implementing NOS into climate change education should not be seen as an easy solution to develop students decision-making skills, but rather, as a tool to help them understand the trustworthiness of science, enabling them to better evaluate statements made of climate scientists and climate change denialists.

Addressing Technological Aspects:

Students' questions suggest that they are interested in learning about new technological innovations and renewable energy, and how their adoption contributes to climate change mitigation. To address these questions, examining innovative technologies would seem to be of interest to some students. However, from the perspective of systems thinking, in addition to understanding how the technology works, it would be important to understand its role in society from a broader perspective. The reason for this is that history has shown that mere technological innovations do not solve environmental problems (Commoner, 1972; Ehrlich & Holdren, 1971).

To understand technology's role in society, at least the role of price, subsidies and consumption should be considered. As an example, for a new technology to be adopted, the price needs to be competitive. This may require government support, such as subsidies (Goldberg, 2001), requiring a political decision-making process. Furthermore, technological advancements can have an increasing effect on consumption (Hynes, 1993), reducing the total benefit gained from adopting the technology. Because of such feedback loops, when considering the environmental impact or benefits of a new technology, it is not enough to consider the technology as a lone entity, but other factors, such as population size and consumption should also to be considered (see Ehrlich & Holdren, 1971).

Addressing Societal Aspects:

Many participants asked questions on *Solutions to climate change*, *Effects on humans*, and *Human action*. To answer these questions, several societal aspects, such as politics and economics, should be considered simultaneously.

Hynes (1993) and many others have argued that in order to overcome climate change, a combination of scientific/technological solutions, societal solutions (e.g. politics) and individual behavior (e.g. reducing consumption) is required. Therefore, to answer students' questions on the possible *Solutions to climate change*, considering these different aspects is important. As was discussed in the previous section, technological developments play their part, but individual (e.g. psychological), economic, regional and political aspects also play a major role. As an example, nations (especially smaller ones) have a limited capacity to act individually, because their economy is tied to the global economy, making global agreements on climate change mitigation important. So, as has been highlighted by Stevenson (1987; 2007), understanding how governments operate, is important in environmental education. One way to bring forth this conversation would be to examine timely issues, such as the Paris 2015 agreements, and how hard, yet important, such global agreements are. Furthermore, education should examine the impact of individuals' mitigative actions on society. As an example, when individuals start changing their consumption patterns from an environmentally harmful product to a friendlier product, the rule of supply and demand will start to bring down the price of the environmentally friendly product, making it more appealing to the general public. This has already been seen in the decrease in prices of solar panels and wind turbines (Hirth, 2013).

In order to address questions related to the *Effects on humans*, it is crucial to understand that climate change will affect different countries and groups of people in different ways and intensity (see IPCC, 2014), and that the environmental, societal and economic effects are strongly linked to each other. As an example, some regions will not be affected by the environmental changes as strongly as others. This may decrease their willingness to take mitigative actions and instead, focus solely on economic growth. However, by choosing to focus on economic growth, the country may need to increase their fossil fuel consumption, further contributing to climate change. In another region, this may lead to more severe effects of climate change, leading to people leaving their homes as climate refugees. A mass migration of climate refugees will then impact even those countries that were not directly impacted by the environmental changes caused by climate change. As this example shows, and as Andrey and Mortsch (2000) have also discussed, climate change is a global issue where different individuals and countries are affected in different ways, yet all are affected. Also in this regard, systems thinking is needed to be able to understand how climate change affects humans.

Addressing Individual Aspects:

Students also asked questions related to them as individuals and as members of a society. Some students wanted to know how to *Raise Awareness* and others, how to act more responsibly (i.e. *Practical Solutions*).

When it comes to personally responsible actions, students should be given the opportunity to examine their behavior and look for alternative ways of doing things. Such self-reflection can help students grow in action competence (Jensen & Schnack, 2006)) and understand what type of actions they would be ready to take. This reflection also opens up room for discussing the relationship between knowledge and behavior. Earlier research has shown that providing people with knowledge on environmental issues will not directly translate into a change in attitude and behavior, but rather, human behavior is affected by a multitude of different aspects, including values, altruism, convenience and economy (Kollmuss & Agyeman, 2002). Understanding this is especially important for those students who want to raise awareness of others. It is also important for them to understand that individual actions tend to revolve around actions with "low-impact", such as recycling (Steg & Vlek, 2009). One reason for this may be that individuals consider certain actions, such as recycling, to have a larger impact on the environment than they actually do (Skamp, Boyes & Stanisstreet, 2013). Therefore, when considering how to raise the awareness of others, it is important to know which "high-impact" actions students are least aware of. A recent study by Skamp *et al*. (2013) suggests that one area worth targeting is the impact of meat consumption, as students are relatively unaware of its impacts, yet they seem relatively willing to take action to reduce their meat consumption. However, environmental impact should not be the only measure by which the benefits of different actions are analyzed, as some actions may empower students to take more significant actions in the future.

Finally, it is important for students to understand that people take actions in different ways. Some take personally responsible actions, such as riding a bike, while others take socially responsible actions or future oriented actions (Vesterinen, Tolppanen & Aksela, 2016). However, as these are very different in nature, comparing them with each other is problematic. Therefore, for students to understand the practical solutions to climate change mitigation, it is important that they do not seek one single answer only, but see the solutions as an array of different actions that can be taken, some fitting one's personal life better than others. More important than taking a certain "right action", it is important to build a mindset of constant reflection, which then helps re-orient one's own actions.

Addressing Aspects of Values:

The questions demonstrate that students want to know the most effective solutions for climate change mitigation. However, as climate change mitigation is a wicked problem (see Levin, Cashore, Bernstein & Auld, 2012), society does not yet know the best actions, or even understand the full nature of the problem we are facing. Each action or non-action will have some positive and some negative effects. As Sterling (2010) had discussed, students should understand the sense of urgency, yet critically analyze the actions that are taken. In order to do this holistically, students should simultaneously consider the three dimensions of sustainable development: the environment, the society and the economy. For instance, something that has a fast positive effect on the environment may have a big negative effect on the economy, especially to people living in a certain region or working in particular industries. For instance, unemployment rates may rise rapidly, which tend to lead to other societal challenges, such as insurgencies (Campante & Chor, 2012). On the other hand, making changes slowly may cause further environmental degradation, causing economic and societal problems in the long run. Therefore, depending on what one values and which region of the world one comes from, different solutions may be considered to be the best. In order for students to gain a holistic view on climate change and climate change mitigation, the underlying ethical issues and different viewpoints of people should be understood.

Students' questions also show that they are unsure about whether climate change is human-induced. Hence, in addition to discussing the scientific phenomena and the NOS, it is important for students to understand that their own views will easily be influenced by others (McKenzie-Mohr, 2013). As climate change is a media issue (see Schreiner *et al*., 2005), students are constantly being influenced by the values of those media channels and the people who write them. Educational researchers have been discussing the importance of increasing students' media literacy and critical thinking (Hodson, 2011). In climate change education, this should also mean students trying to look, not only into the trustworthiness of the statements, but also into the values of those making these statements: A solution that benefits a certain country or a certain company, may not have global benefits.

A pedagogical approach to addressing students' questions

In order to address students' questions holistically and to support students' development into systemic thinkers, we argue that, rather than giving direct answers to students' questions, the teacher should direct the students towards guided inquiry: a process in which students attain knowledge from several sources and examine their questions from different perspectives (see Kuhlthau, Maniotes, & Caspari, 2015. A teacher with sufficient content knowledge on climate change may guide this inquiry process by first asking the student questions that help break down their original question into smaller questions, and then directing them to look at the big picture again. An imaginary guided inquiry conversation between a teacher and a student may proceed like this:

> Student: *How can we make renewable energy sources cheaper and more available to the public?*
>
> Teacher*: What do you think affects the price of renewable energy sources, or any product for that matter?*
>
> *(After some research)*
>
> Student*: Price is affected by supply and demand, as well as by the price of raw materials and production cost.*
>
> Teacher*: How could the supply and demand of renewable energy sources be affected?*
>
> *Student: We would either need more companies producing renewable energy or more people using it.*
>
> *Teacher: How could the government impact the amount of companies producing renewable energy?*
>
> *Student: They could give them money to produce renewable energy*
>
> *Teacher: Yes, they could, and this would bring down the price of renewable energy. And what would happen then?*
>
> *Student: As the price comes down, people would start to use it more.*
>
> *Teacher: Yes, and what will this do to the production of renewable energy sources, such as solar panels?*
>
> *Student: More will be produced, making production cheaper.*
>
> *Teacher: Yes, so it seems that by giving government support to certain companies, the use of renewable energy could be increased. Now why would governments want to support companies and where would the money come from?*

As the example shows, a guided inquiry process can be directed towards dealing with several important issues related to climate change, which were not explicitly present in the student's original question. Furthermore, guided inquiry can be used to expand the discussion beyond the obvious, but overly simplistic conclusions that may first come to mind. By doing so, the teacher may help the students understand how complex an issue climate change and climate change mitigation and adaptation are. Most importantly, guided inquiry is a stepping stone to systems thinking as it helps the student expand their thoughts on an issue or question, by forcing them to examine related components. With practice, the student may learn to ask themselves similar questions to what their teacher would ask. Mastering such `self-guided enquiry´ would help a student attain the knowledge needed to build `the big picture´, needed for systems thinking.

During the process of guided inquiry, there are several aspects that should be considered to help ensure that the issue is dealt with holistically. To help in this process, it is useful to ask the following questions during the guided inquiry process:

1. How is this question related to climate change science and technological innovation?
2. How is this question linked to society e.g. politics and economy?
3. How is this question related to individual behavior e.g. psychology and ethics?

To deal with the questions holistically, it is then important to examine how the answers to these three questions are linked to each other. As an example, one could examine how the students original question is linked to technological innovation (question 1) and how that is then linked to individual behavior (question 3).

Furthermore, implementing student-centered project-based approaches would give students time to dig deeper into an area of climate change, which most interests them (Krajcik, Blumenfeld, Marx, & Soloway, 1994). However, as the students' questions suggest, the projects should be cross-disciplinary, organized together with several subject teachers. In a case study conducted by Tolppanen and Tirri (2014), such a project was implemented in a non-formal education program over a period of two months. During this process, students had a mentor who helped the students construct their understanding of the topic by guiding them to research articles, internet resources and to experts. Research on the working-process shows that such a process is meaningful for learning (Tirri, Kuusisto, & Aksela, 2013) and that the students enjoyed the process (Tolppanen & Aksela, 2013). After completing the projects, the groups presented their work to each other, permitting them to learn from each other (Tolppanen & Aksela, 2013). In collaboration with different subject teachers, such a project could also be implemented into schools. In such projects, teachers should guide the students to use both local and global databases when examining the effects of and solutions to climate change.

Earlier research has suggested that dialogues and debates should be used to help students construct their own ideas on environmental issues (González-Gaudiano & Meira-Cartea, 2010; Zeidler & Nichols, 2009). However, we would argue that debates on climate change and climate change mitigation will not benefit the learners, unless a deep understanding on the issue has already been reached. The reason for this is that unless the multifaceted nature of climate change is understood, opinions will often be simplistic and inaccurate. Disseminating such ideas in an environment where no one else has sufficient knowledge to counter the claims, the perpetuate misconceptions may stick as truths. However, debates could be a useful tool towards the end of a learning module, as they give the opportunity for students to discuss what they have learned. Furthermore, if the teacher has a sufficient level of content knowledge on climate change, student debates can help the teacher see some of the misconceptions that the students still hold about climate change and climate change mitigation.

Limitations of the Study

Firstly, the participants in this study come from various backgrounds and therefore the student's previous climate change education differs from each other's. Within the limits of this study, it was impossible to consider how these different backgrounds affect what students find relevant in climate change education, but it may be assumed that previous knowledge does influence the type of questions students ask. However, as climate change is a media issue, similar background differences would be found in any given heterogeneous classroom. Though the questions within any given classroom may differ, this study shows that the range of questions is wide, and that answering students' questions is not a simple task, but requires a holistic, multidisciplinary approach.

Secondly, the participants in this study were presumably all scientifically oriented and interested in climate change. Due to student's scientific orientation, the quantity of different types of questions may be different in a more heterogeneous group. However, as the primary focus of this study was on the qualitative nature of the questions, students specific interest towards science is not a limitation to the transferability of the findings. A bigger limitation is the fact, that the questions analyzed in this study are asked by students interested in climate change. It is obvious that in a heterogeneous classroom, not everyone will be interested in climate change, nor be able to ask such diverse questions about climate change, as was seen in this study. Therefore, not all the aspects of a holistic approach or the suggested pedagogical methods can be applied. In such cases, a teacher needs to use their pedagogical skills to examine how the content and methods could be applied to such students. Due to these limitations, further empirical studies are needed on how well the holistic approach suits classroom practice. The authors realize that changing pedagogical practice may bring problems that are not considered in this paper, and that suggestions presented in this paper will not solve the structural problems present in schools (see: Stevenson 1987; 2007). Furthermore, if a national curriculum does not see the importance of dealing with climate change from an individual, societal and vocational perspective, teachers may also lack the motivation to do so. Therefore, the relevance of climate change education needs to be considered also by curriculum developers.

CONCLUSIONS

This paper first outlines some of the structural, pedagogical and content challenges of climate change education. Based on the *Climate System* theoretical framework, we argue that a systemic approach is called for in climate change education. This argument is supported by the results of this study, which reveal that students ask a diverse array of questions that are multidisciplinary in nature. This array of questions represents the same themes as those identified in the literature as important for climate change education. Based on this link between theory and practice, we argue that students should be given more opportunities to explore answers to their own questions through a process of teacher guided inquiry.

The paper also highlights the challenges involved in responding to students' climate change questions. One of the main challenges is that climate change is a complex issue involving environmental, cultural and political understandings and values that are partly reflected in students' questions which often touch on several different aspects simultaneously. Addressing these questions requires multidisciplinary pedagogical approaches that promote student inquiry and systems thinking. However, implementing such approaches is typically made difficult by the dominant historical purposes and structures of school systems (see Stevenson, 2007) and a current climate of narrow accountability measures. Therefore, to advance climate change education, more research is needed on how governments, principals and teachers can help ease the tension between old educational structures and new pedagogical approaches.

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